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Research Article

Biostimulatory effect of seaweed extract on the fruiting and runner production of Strawberry

Vishal Singh Rana, Kusum Lingwal, Sunny Sharma, Neerja Rana, Ravina Pawar, Vijay Kumar, Umesh Sharma

Abstract

The strawberry plant is an herbaceous perennial and having a shallow root system needs effective nutrient management. The conventional farming system involves the enormous use of chemicals which leads to the degradation of plant and soil health. On the contrary, organic fruit production is more beneficial for plant health and organic fruit production has gained momentum due to increasing the cost of fertilizers and growing ecological concerns. Seaweed extracts are considered an organic farm input as they are environment-friendly and safe for human health. Keeping in view the bio-stimulatory potential of seaweed extracts, a study was conducted to elucidate their effect on the blooming, yield, quality, and runners' production of strawberries under polyhouse conditions during the year 2018-19. The seaweed extract (SWE) was used at variable concentrations *viz*, 0.75 ml L^{-1}, 1.0 ml L^{-1}, and 1.25 ml L^{-1} which were applied at the pre-flowering stage (PFS) or Fruit set stages (FSS) or both the stages (PSS and FSS). The study revealed that the foliar spray of seaweed extract at pre-flowering and fruit set enhanced the blooming characteristics and runner production. Furthermore, the plant treated with 1.0-1.25 ml L^{-1} seaweed extract at the pre-flowering and fruit set stage exhibited the highest cumulative yield and better fruit quality characteristics.

Keywords biostimulants, runner production, seaweed extract, strawberry

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Authors:
V. S. Rana, K. Lingwal, S. Sharma ✉,
R. Pawar, V. Kumar
Department of Fruit Science, College of Horticulture, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh 173230, India

N. Rana
Department of Basic Science, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh 173230, India

U. Sharma
Department of Tree Improvement and Genetic Resources, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh 173230, India

✉ sunnysharmafsc@yspuniversity.ac.in

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Introduction

The Strawberry is one of the most fascinating fruit crops linked with early summer, intense flavor, delicious aroma, and texture [1]. In India, it is cultivated in an area of 1000 ha with a production of 8000 tonnes [2]. The agro-climatic conditions of Himachal Pradesh are congenial for strawberry cultivation. The area under strawberry cultivation in Himachal Pradesh is 49 ha and production is 30 Metric Tonnes [3]. It is grown commercially in the Sirmour, Solan, Shimla, Kullu, Kangra, and Una districts of the state. In lower hills, the strawberry is grown for fruit production, while in higher hills it is mainly grown for runner production. The fruit is now available around the year as strawberries are grown under protected structures, which either prolong or progress their availability in the market. Organic strawberry production has now gained importance due to its high nutritional quality and favorable antioxidant characteristics [4]. The productivity of the organic system is increasing

and sustainably oriented producers are now looking for novel methods and technological advances which may positively affect fruit quality, yield, and fruit formation in strawberries early in the season.

Biostimulants are a novel improvement in cropping systems that advance vegetative growth, development, and yield, promoting root formation, and ameliorating nutrient uptake [5]. Several seaweed species (macroalgae) possess growth-promoting characteristics and have been used in their raw form in crop production. More recently, these marine organisms are available as extracts and frequently applied to horticultural crops as they exhibit positive effects on flowering, yield, and nutritional quality of the fresh produce [6]. Brown algae are mainly used for commercial applications in organic horticulture and among them; Seaweed extracts are one of the most popular. Seaweed extracts are rich in a diverse range of inorganic and organic constituents which interact synergistically and enhance the growth of various crops [7].

The early cropping of strawberries under a protected structure is the need of the hour and the present study was planned to evaluate the effect of seaweed extract on runners, fruiting, and quality of organic strawberry cvs. Camarosa, Chandler, and Winter Dawn. Besides eliciting a growth-promoting effect on the seaweed extracts also enhance soil health by improving moisture-holding capacity and by promoting the growth of beneficial soil microbes. The bio-stimulatory potential of many seaweed products has not been fully exploited in the growth, yield, and quality of strawberries in India. Keeping in view the above facts, the present investigation was undertaken to elucidate the effect of seaweed extract on blooming, yield, and quality characteristics as well as runner production of strawberry cvs. Camarosa, Chandler, and Winter Dawn.

Methodology

The present investigation was conducted to elucidate the influence of seaweed extract on blooming, yield, quality, and runner production of strawberries under polyhouse conditions during the year 2018-19 in an experimental block of the Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh). The experimental location is located at 30°51’ N latitude and 77o 10’ East latitude at an elevation of 1310 m above mean sea level. The flat beds of 1 m × 1 m size were prepared and healthy runners of three strawberry cultivars namely; Camarosa, Chandler, and Winter Dawn procured from research stations of the university were planted at a spacing of 60 cm × 45 cm during the first week of October. All the cultural practices viz., irrigation, fertilization, weeding, mulching, and pest control were done uniformly according to a package of practices of the university. The experiment was laid out in a Randomized Block Design with ten treatment combinations and each treatment was replicated thrice. The seaweed extract (SWE) was used at variable concentrations *viz*, 0.75 ml L^{-1}, 1.0 ml L^{-1}, and 1.25 ml L^{-1} which were applied at the pre-flowering stage (PFS) or Fruitset stages (FSS) or both the stages (PSS and FSS). The seaweed extract used in the research trial was ‘Agrogain’ which is a patented biostimulant of the company SEA6 ENERGY PVT. LTD.

Various observations were taken during the experimentation. The total number of runners per bed was counted at the end of the growing season and then the average number of runners per plant was calculated. The observation of the initiation of flowering was recorded when the first flower opened. The dates when more than a percent of flowers opened in the marked plants were reckoned as dates of full bloom. The fruit set was recorded when all the petals had fallen after the full fruit set. The total number of days from the initiation of flowering to the end of flowering was counted and results were expressed as the duration of flowering. The size of the fruit was measured in terms of length and diameter of ten randomly selected fruits in each harvest and measured with the help of Digital Vernier Calliper. The values were expressed in millimeters (mm). The sugar content and ascorbic acid content were determined as per the standard procedures given by the Association of Official Agricultural Chemists [8]. The sugar/acid ratio was calculated by dividing the

percent sugars by that of the corresponding percent titratable acidity. The data obtained on various parameters were analyzed using MS-excel and OPSTAT as per the design of the experiment (RBD, factorial) for working out the Analysis of variance (ANOVA) as suggested by Gomez and Gomez [9].

Results and Discussion

The data about the effect of seaweed extract on the date of initiation of flowering in strawberry plants are illustrated in Figure 1. The initiation of flowering was advanced by almost all the seaweed extract treatments when applied at the pre-flowering stage of the plant. The application of SWE at the fruit set stage of the plant did not advance flowering much as compared to the pre-flowering stage. The earlier initiation of flowering in Winter Dawn followed by Camarosa and Chandler has also been recorded [10-11].

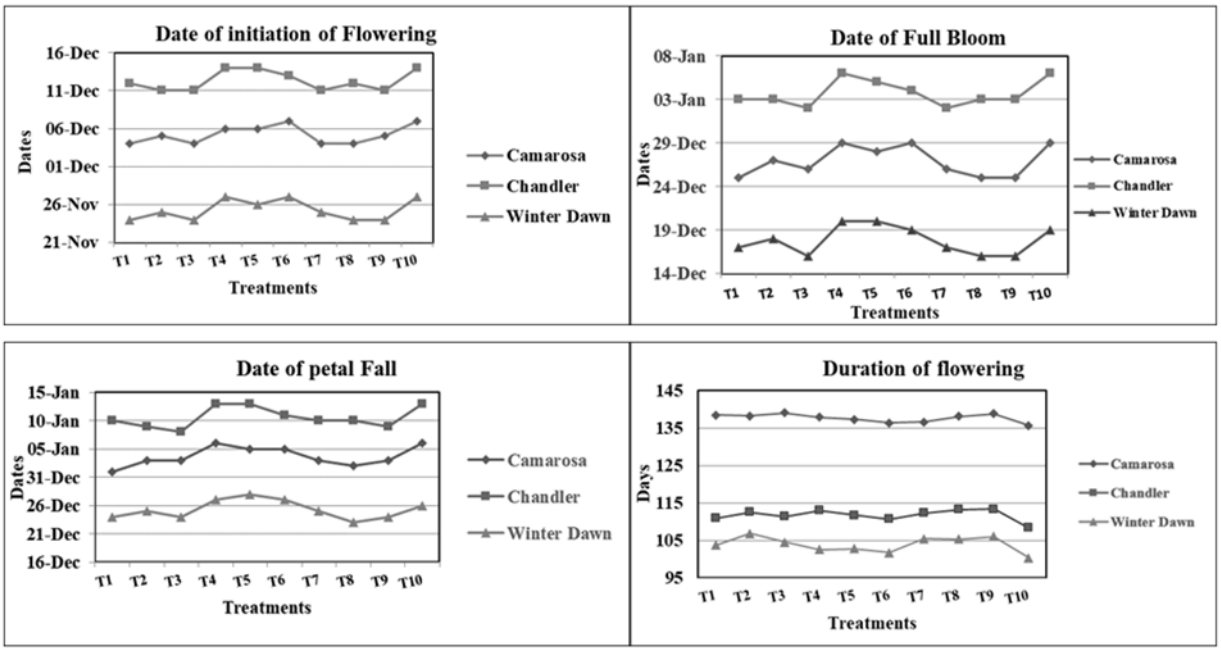

Figure 1. Influence of seaweed extract on the blooming characteristics of strawberry

The advancement in the initiation of flowering due to SWE treatments might be due to the presence of growth regulators like (cytokinin and auxin) in SWE which are known to promote early flowering in strawberries [12]. The results in the present study are also in agreement with the findings of Crouch and van Staden [13]. The seaweed extract has been known to trigger early flowering and fruit set in the number of crops which might be due to robust plant growth when applied at the initial growing stage of the plant.

The time of full bloom also varied among different strawberry varieties. The early full bloom in Winter Dawn followed by Camarosa and Chandler, followed more or less the similar pattern as that of flower initiation. The variety which initiated early flowering attained earlier full bloom and similarly, the treatments of SWE that enhanced flowering resulted in earliest date of full bloom. SWE also influenced the date of full bloom and followed a more or less similar pattern as that of initiation of flowering. A perusal of data clearly showed that seaweed extract treatments initiated earlier petal fall (fruit set) when applied at pre-flowering alone or twice at pre-flowering and fruit set the stage as compared to fruit set alone and control. The date of petal fall in Winter Dawn was the earliest, followed by Camarosa. The Chandler enhancement in the vegetative growth of the plant by the

application of seaweed extract during the pre-flowering stage as discussed earlier might have resulted in the formation of more metabolites and therefore enhanced the date of petal fall as compared to SWE treatments at fruit set. It is revealed that seaweed extract had a significant effect on the duration of flowering (Figure 1). The maximum duration of flowering was noticed with SWE 1.25 ml L^{-1} at the pre-flowering and fruit set. The data also showed that the maximum duration of flowering was noticed in the cultivar Camarosa which was followed by Chandler and Winter Dawn. The interactions between SWE treatments and cultivars revealed that the maximum flowering duration (139.05 days) was recorded with Camarosa treated with SWE 1.25 ml L^{-1} at pre-flowering. The results of the present study are supported by Sahu [10] and Bhamini et al., [11]. The increment in flowering duration in SWE treatments might be closely linked to the increment in vegetative growth characteristics. The difference in flowering characteristics amongst different cultivars may be due to the inherent characteristics of the genotypes, stage of growth, day length, and temperature.

The SWE treatments and cultivars revealed that the highest cumulative yield per plant was recorded in the cultivar Winter Dawn treated with SWE- 1.0 ml L^{-1} at pre-flowering and fruit set Figure 2. The lowest cumulative yield per plant (288.12 g/plant) was recorded with a treatment combination of Chandler without Seaweed treatment. The yield increment in seaweed extract-treated plants might be linked to the increase in vegetative growth characteristics of the plant that leads to the increase in flower number and better fruit set [14]. Photosynthate distribution could be shifted from vegetative parts to the developing fruits during fruit development by cytokinin. Fruits treated with SWE had a higher concentration of cytokinin than the untreated fruits. Higher cytokinin levels have also been reported in the roots of seaweed extract-treated plants [14]. Similar results were also recorded by Agnieszka et al., [15], Spinelli et al., [16], and Alam et al., [5] in strawberries.

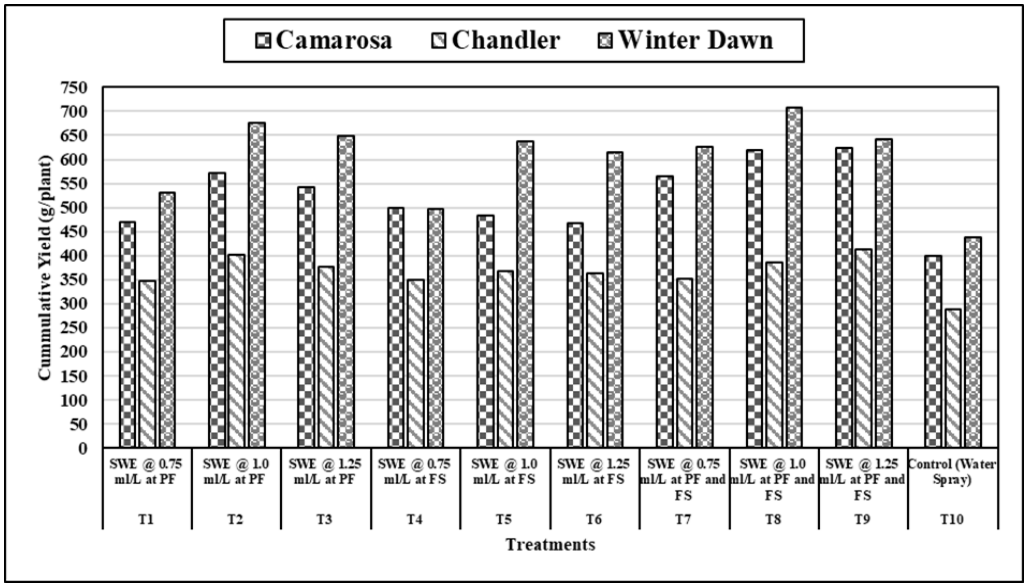

Figure 2. Influence of seaweed extract on the cumulative yield of strawberry cultivars

The data on the effect of seaweed extract on the number of runners per plant in strawberries are depicted in Figure 3. A perusal of the data revealed that the highest number of runners per plant was recorded with the application SWE- 1.25 ml L^{-1} at PFS and FSS. The Chandler cultivar recorded the highest number of runners per plant, followed by Winter Dawn and Camarosa. The SWE treatments and different cultivars did not show any significant effects on the number of runners per plant. The results obtained in the present study indicated an increment in the runner production by SWE a treatment which is in close conformity with the findings of Mattner et al., [17] who also observed increased runner formation with the application of SWE in strawberries. The presence of

growth regulators like GA3 in SWE might have increased cell division, cell elongation, and a corresponding increase in parenchyma cell length leading to more runner production. The increment in runner formation with the exogenous GA3 application has also been reported by Ahire et al., [18] and Kumar et al., [19] in strawberries. The differences in runner production among different strawberry cultivars understudy may be due to the varietal character.

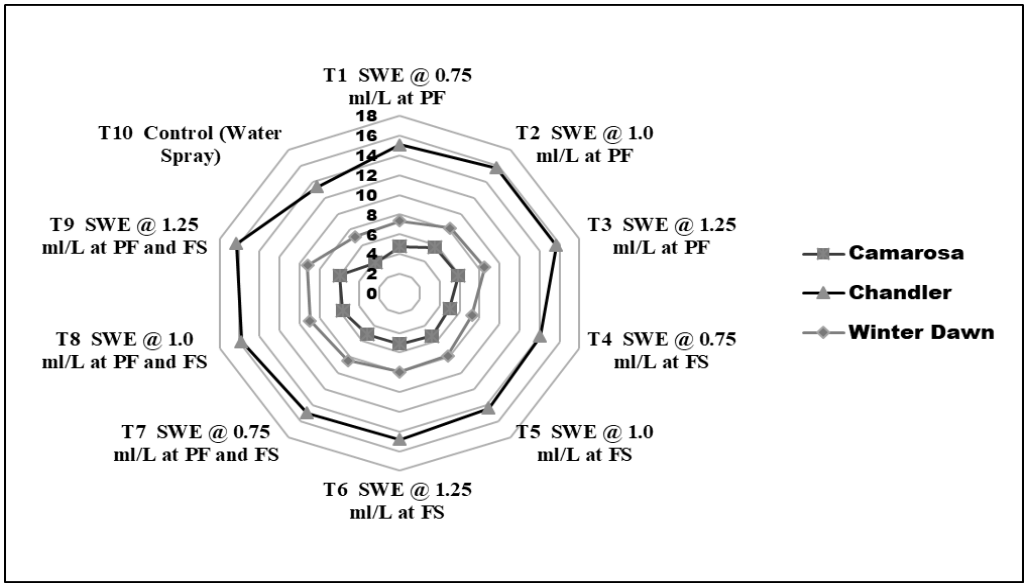

Figure 3. Influence of seaweed extract on the runner production of strawberry

The fruit size as influenced by SWE treatments and cultivars also recorded significant differences in the fruit length (Table 1). The highest fruit length was recorded in the cultivar Camarosa treated with 1.25 ml L^{-1} SWE at pre-flowering and fruit set. Whereas, the lowest fruit length was recorded in cultivar Chandler without SWE treatment which was significantly lower than all the SWE treatments. The cultivars also exerted a significant influence on the fruit's breadth. The highest berry breadth was recorded in the cultivar Camarosa followed by Winter Dawn and Chandler. The interactions between SWE treatments and cultivars exhibited non-significant effects on the fruit breadth. The results obtained in the present study are in conformity with the findings of Musawi [20] in sour oranges and Abd El-Motty et al., [21] in mango. The significant increase in the fruit length of berries might be due to the presence of growth regulators like GA, auxin, and cytokinin in SWE. Auxin is responsible for the receptacle enlargement in strawberries through cell division. Gibberellic acid also increases cell division and cell elongation and it has been reported to promote growth by increasing the plasticity of the cell wall, followed by hydrolysis of starch into sugar. This reduces the cell wall potential and results in the entry of water into the cell, causing its elongation [22].

SWE treatments and cultivars also exerted significant effects on sugar contents (Table 2). The highest total sugar contents were recorded in cultivar Chandler treated with 1.25 ml L^{-1} SWE at pre-flowering and fruit sets. Whereas, the lowest total sugar contents were recorded in a cultivar of Camarosa without SWE treatment. The highest reducing sugars were recorded in the treatment combination of cultivar Chandler with SWE - 0.75 ml L^{-1} at the pre-flowering and fruit set. Whereas, the lowest reducing sugars were recorded with a cultivar of Camarosa without SWE treatment. The highest non-reducing sugars were recorded in cultivar Chandler treated with SWE - 1.25 ml L^{-1} at pre-flowering and fruit set. However, the lowest non-reducing sugars were recorded in cultivar Chandler treated with SWE - 0.75 ml L^{-1} at the pre-flowering and fruit set.

Table 1: Influence of seaweed extract on the fruit dimensions of strawberry fruits

Code	Treatment details	Fruit Shape dimensions							
		Fruit length (mm)				Fruit diameter (mm)			
		Camarosa	Chandler	Winter Dawn	Mean	Camarosa	Chandler	Winter Dawn	Mean
T1	SWE-0.75 ml L^{-1} at PF	40.17	37.21	38.68	38.68	30.70	26.14	27.75	28.20
T2	SWE-1.0 ml L^{-1} at PF	44.04	38.47	39.63	40.72	32.90	28.07	29.96	30.31
T3	SWE- 1.25 ml L^{-1} at PF	41.47	38.83	41.03	40.44	30.74	27.63	29.80	29.37
T4	SWE- 0.75 ml L^{-1} at FS	43.31	37.71	38.58	39.86	30.71	26.14	28.41	28.42
T5	SWE- 1.0 ml L^{-1} at FS	40.92	38.85	39.84	39.87	29.34	26.25	29.16	28.25
T6	SWE- 1.25 ml L^{-1} at FS	39.74	38.36	39.00	39.03	30.05	25.77	29.50	28.44
T7	SWE- 0.75 ml L^{-1} at PF and FS	41.13	37.19	39.60	39.31	31.17	26.10	28.64	28.64
T8	SWE- 1.0 ml L^{-1} at PF and FS	45.47	38.90	42.56	42.31	31.49	27.00	29.69	29.39
T9	SWE- 1.25 ml L^{-1} at PF and FS	46.41	39.14	42.09	42.54	32.23	28.24	30.37	30.28
T10	Control (Water Spray)	39.05	33.34	36.32	36.24	26.81	23.01	26.87	25.56
	Mean	**42.17**	**37.80**	**39.73**		**30.61**	**26.43**	**29.01**	
	$LSD_{(0.05)}$ T V T x V	0.77 0.42 1.34				0.87 0.48 NS			

SWE: Seaweed Extract, **PFS:** Pre Flowering Stage, **FSS:** Fruit set Stage, **LSD:** Least Significant Difference, **T:** Treatment, **V:** Cultivar

Table 2. Influence of seaweed extract on the chemical characteristics of strawberry fruits

Code	Treatment	Sugars (%)												Ascorbic acid (mg/100g of Fresh fruit weight)			
		Total				Reducing				Non reducing							
		Camarosa	Chandler	Winter Dawn	Mean	Camarosa	Chandler	Winter Dawn	Mean	Camarosa	Chandler	Winter Dawn	Mean	Camarosa	Chandler	Winter Dawn	Mean
T1	WE -0.75 ml L^{-1} at PF	5.40	6.42	5.85	5.89	3.31	4.55	3.91	3.92	1.97	1.77	1.84	1.86	40.43	52.17	41.28	44.63
T2	WE - 1.0 ml L^{-1} at PF	5.66	6.55	6.12	6.11	3.28	4.51	4.06	3.95	2.26	1.94	1.95	2.05	42.41	53.65	46.16	47.41
T3	WE - 1.25 ml L^{-1} at PF	5.80	6.96	6.23	6.33	3.23	4.33	4.23	3.93	2.43	2.50	1.90	2.28	40.89	52.34	42.62	45.28
T4	WE - 0.75 ml L^{-1} at FS	6.06	6.36	5.96	6.13	3.04	3.97	3.96	3.66	2.87	2.27	1.91	2.34	39.97	50.58	41.28	43.94
T5	WE - 1.0 ml L^{-1} at FS	5.40	6.63	5.97	6.00	3.14	4.17	4.26	3.85	2.14	2.33	1.62	2.03	41.86	52.60	42.36	45.61
T6	WE - 1.25 ml L^{-1} at FS	5.30	6.44	6.4	6.04	2.87	4.13	4.09	3.70	2.30	2.59	2.19	2.36	40.81	53.36	40.87	45.01
T7	WE - 0.75 ml L^{-1} at PF and FS	5.33	6.86	6.13	6.10	3.13	4.65	3.91	3.90	2.08	1.70	2.01	1.93	40.12	53.27	40.84	44.74
T8	WE - 1.0 ml L^{-1} at PF and FS	5.51	7.04	6.29	6.28	3.14	4.30	4.17	3.87	2.54	2.31	2.10	2.32	40.42	56.34	43.13	46.63
T9	WE - 1.25 ml L^{-1} at PF and FS	6.03	7.48	6.57	6.69	3.35	4.60	4.06	4.00	2.25	3.02	2.39	2.55	43.03	56.88	41.73	47.20
T10	ontrol (Water Spray)	5.20	6.14	5.70	5.68	2.73	3.76	3.73	3.40	2.34	2.26	1.87	2.15	39.44	49.59	37.33	42.12
	Mean	**5.57**	**6.69**	**6.12**		**3.12**	**4.29**	**4.04**		**2.32**	**2.27**	**1.98**		**40.94**	**53.08**	**41.76**	
	$LSD_{(0.05)}$																
	T	0.18				0.15				0.20				1.47			
	V	0.10				0.08				0.11				0.81			
	T×V	0.31				0.26				0.36				2.56			

SWE: Seaweed Extract, **PFS:** Pre Flowering Stage, **FSS:** Fruit set Stage, **LSD:** Least Significant Difference, **T:** Treatment, **V:** Cultivar

The results of the present study revealed that the total sugars reducing and non-reducing sugars contents were significantly increased with the foliar application of SWE. The increase in sugar content might be attributed to the higher accumulation of photo-assimilates in fruits of plants treated with seaweed extract. These results are in close conformity with the findings of Khan et al., [23] who reported that foliar applications of a mixture of amino acids and seaweed extract in grape vines exhibited significantly higher total sugars and reducing sugars as compared to other treatments.

The data on the sugar-acid ratio as influenced by SWE treatment and cultivars are depicted in Figure 4. The highest reducing sugars were recorded in the treatment combination of cultivar Winter Dawn with SWE - 1.25 ml L^{-1} at pre-flowering and fruit set which was followed by Camarosa and Chandler. The results of the increment in sugar/acid ratio with the application of SWE are in close conformity with the findings El-Moniem et al. [24] in grapes. The TSS/acid ratio determines the flavor of fruit which suggest that the fruits of Winter Dawn and Chandler are better in taste than the Camarosa which is slightly sour.

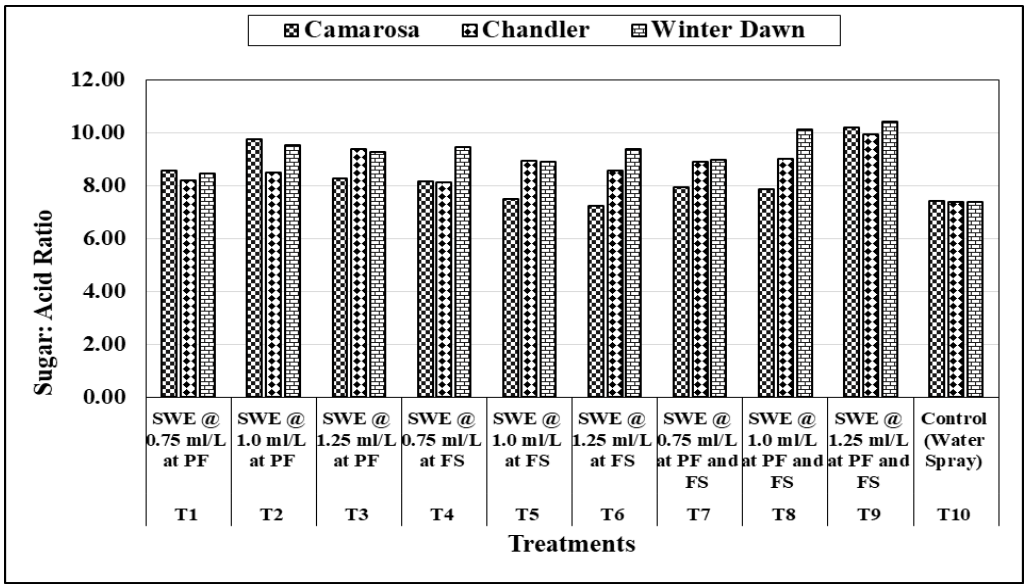

Figure 4. Influence of seaweed extract on the sugar-acid ratio of strawberry cultivars

The application of SWE significantly increased the ascorbic acid content of fruits concerning control (Table 2.) The maximum ascorbic acid (56.88 mg/100g) was recorded in a treatment combination of cultivar Chandler with SWE at the rate of 1.0 ml L^{-1} at the pre-flowering and fruit set. The increment in ascorbic acid content might be due to a higher supply of photoassimilates in fruits treated with seaweed extract. The present results also get support the findings of Musawi [20] also obtained the maximum ascorbic acid with algal extract application in sour oranges.

Conclusion

It is concluded from the present study that the foliar spray of seaweed extract at pre-flowering and fruit set enhanced the blooming characteristics and runner production. Furthermore, the plant treated with 1.0-1.25 ml L^{-1} seaweed extract at the pre-flowering and fruit set stage exhibited the highest cumulative yield and better fruit quality characteristics.

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